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MINE SAFETY DEVICES DEVELOPED BY THE UNITED STATES BUREAU OF MINES

BY

VAN. H. MANNING
Director, U. S. Bureau of Mines

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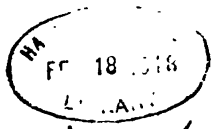

Smithsonian Institution

MINE SAFETY DEVICES DEVELOPED BY THE UNITED STATES BUREAU OF MINES.

By VAN. H. MANNING, *Director.*

[With 7 plates.]

The present article outlines the character and the method of use of some of the more important devices developed by the Bureau of Mines in its investigations looking to greater safety in mining, and discusses the bureau's work in educating and training miners to protect themselves from harm and in furthering the use of safer explosives and equipment in mines. Although the Bureau of Mines is investigating conditions, methods, and equipment in the quarrying, metallurgical, and other mineral industries as well as in mining, this article deals particularly with appliances used in coal mining.

MINE RESCUE AND FIRST-AID WORK OF THE BUREAU OF MINES.

In its mine safety and first-aid work the Bureau of Mines has four main objectives, as follows:

First. To investigate and report on mine accidents to the end that their causes may be more thoroughly understood and the mine operators advised as to the best means of avoiding them.

Second. To teach the use of oxygen mine-rescue apparatus and the methods of performing first aid to the injured.

Third. To send trained rescue crews to the scenes of explosions, fires, or other accidents in order to save life and property.

Fourth. To acquaint mining men with safe and unsafe mining practices through lectures, conferences, motion pictures, and the wide but judicious distribution of its publications.

During the fiscal year 1916, 89 accidents were investigated and a thorough report made on each. If a given report indicated that electricity had been a contributory cause of the accident the matter was referred to the bureau's electrical engineers for consideration and recommendations as to ways of preventing similar accidents. Similarly problems concerning explosives, mine gases, and the coal dust and other hazards are referred to the bureau's experts.

It is, of course, well understood that mining is a hazardous occupation and that injuries more or less severe are of daily occurrence in large mines. From the very nature of the work, practically all

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men injured underground have to be transported a considerable distance before a doctor sees them, and frequently one to two hours may elapse between the time of injury and the time when the doctor first sees the patient. Consequently it is highly desirable that each miner should understand proper first-aid methods.

Stationed at various mining centers throughout the country the bureau has first-aid miners, men with wide mining and first-aid experience, who have been instructed in standardized first-aid methods by the bureau's mine surgeon. These men either work from the bureau headquarters in their district or are attached to the bureau's mine rescue cars or automobile rescue trucks, on which they travel from town to town, giving without charge a complete course in first aid. The bureau maintains eight such cars and three automobile rescue trucks. The miner is taught how to give artificial respiration, treat shock, control hemorrhage, and bandage any part of the body for fracture, dislocation, wound, or burn, and is shown the best method of transporting an injured person.

Mine rescue methods have been taught in conjunction with the first-aid training. Bureau employees, designated foreman miners, accompany its rescue cars and trucks and teach the miners how to use the principal types of self-contained oxygen rescue apparatus. This apparatus consists of a steel cylinder containing oxygen at a pressure of approximately 2,000 pounds per square inch, with a reducing valve which allows the flow of a definite quantity of oxygen per minute, at a pressure slightly above atmospheric, to pass from the cylinder to a reservoir from which it is breathed by the wearer. The exhaled air flows to a compartment containing regenerating material, usually sodium hydroxide, by which the carbon dioxide of the exhaled air is removed. The regenerated air joins the stream of oxygen from the reducing valve, and the cycle is repeated.

The foreman miners of the bureau give instruction in recovery methods, laying especial emphasis on the use of none but fully manned crews and on the need of the crews having such adjuncts as safety lamps, canary birds (for detecting poisonous gases), life lines, and telephones. It is gratifying to note that but few lives have been lost in the past year through heroic but misdirected and unorganized recovery work. Before the organization of the bureau the loss of lives from this cause was high.

Experiments looking toward a more thorough understanding of rescue apparatus and resuscitators have been carried on at the bureau's Pittsburgh experiment station. Owing to the European war, apparatus formerly made in Germany and England are now made in this country, and it has been necessary to thoroughly inspect and test this American-made material. As a result of these tests

some serious defects were pointed out and these have been remedied by the manufacturers. A new and improved type of apparatus, subsequently described, has been developed by the bureau.

In their training work the bureau's field men observe many instances of safe and unsafe practice, and the knowledge thus gained they utilize through their district in conferences with the miners and the operators. When it is felt that one or more of the bureau's publications will be helpful to a particular miner or operator, the publications are forwarded. When the bureau's field men find gaseous or dusty conditions in mines and these conditions are dangerous or not well understood, they take samples of the air or dust and forward these to the bureau's laboratory for analysis. The information obtained is then available for the operator concerned.

The operators of mines in which adequate consideration is given to safety features are being given reduced rates for workmen's compensation insurance. The benefits to the miners are even greater in that accidental deaths and injuries are being materially reduced.

USE OF MOTION PICTURES IN MINE SAFETY WORK.

In its general mine safety work the Bureau of Mines makes effective use of motion pictures to illustrate (1) safe and unsafe methods and practices and (2) Bureau of Mines standard methods of mine rescue and first aid.

Most of these films are taken by bureau photographers in cooperation with various mining companies; some are purchased, and others are presented to the bureau. They are shown to the mining public by bureau representatives on every possible occasion, largely in connection with mine-rescue and first-aid training. A chronological loan record is kept of past, present, and prospective loans of films. It is estimated that during the past fiscal year films were shown to 160,000 mining people, not including the thousands of visitors to the Government safety-first train.

As these films are for a specific vital educational purpose—to instruct mine workers, many of whom know little of the English language or the work in which they are engaged—the scenarios are, so far as possible, criticized by expert engineers and surgeons.

Stationary photographs, taken with the same educational object, are used to illustrate bureau reports and for lantern slides. That they may be intelligible to non-English-speaking miners, the titles to many of these slides are in four languages.

When the interest of the miners in rescue, first-aid, and general safety work can not otherwise be aroused, a lecture by bureau engineers, with motion pictures or lantern slides of safe practices as contrasted with dangerous practices, enables the lecturer to organize first-

aid and rescue classes, thus starting a safety propaganda where it otherwise would not be received.

NEW FORM OF OXYGEN MINE RESCUE APPARATUS.

After a long period of experiment the Bureau of Mines has developed a new form of oxygen breathing apparatus for use in poisonous or irrespirable atmospheres in mines after fires or explosions. It is called the Gibbs apparatus, after its chief designer, W. E. Gibbs, engineer of mine-safety investigations, of the bureau.

In such apparatus, as it is impracticable to compress into a portable tank enough air to supply the breathing needs of the wearer for the hour or two during which he remains in poisonous atmospheres, pure oxygen is used. In general, an oxygen rescue apparatus consists of a small tank of compressed oxygen, a reducing valve through which the oxygen flows to a mouthpiece connected to the breathing bag by flexible tubes, and a receptacle containing caustic soda for absorbing the carbon dioxide from the exhaled air. Valves that open and close at each breath prevent expired air from returning to the lungs before it has passed through the purifier.

To construct an apparatus of this kind would be relatively simple if it were not for the conditions under which the apparatus is worn. As rescue crews work in the unmapped wreckage following mine accidents, in a presumably irrespirable atmosphere and often in smoke so dense that their electric lamps are of small help, any failure of an oxygen rescue apparatus may mean death to the wearer. Moreover, the labor of exploration and rescue is often arduous, and the apparatus worn must be as light as is consistent with strength and yet strong enough to withstand the hard knocks it is sure to receive. It must be mechanically so perfect that it will not fail to function, and yet be so simple that it can be manipulated with safety in the dark and in surroundings that exhaust the wearer both physically and mentally.

The Gibbs apparatus, developed by the Bureau of Mines, differs from others in the following particulars:

By means of a new form of reducing valve the oxygen is supplied to the user at a variable rate which constantly adjusts itself to his immediate demands.

A new form of carbon dioxide absorber keeps the inspired air pure and prevents it from reaching an uncomfortably high temperature during the two-hour standard period of use.

The pressure gauge, which indicates the available supply of oxygen, is read by touch. Thirty minutes before the supply is exhausted it rings an alarm.

The apparatus, a self-contained unit, is carried wholly on the back of the wearer, so that his arms are unimpeded by the customary front breathing bag and its connections.

An aluminum cover incloses the whole apparatus and protects it from injury.

A pump within the mouthpiece permits the removal of saliva as fast as it is formed.

The weight of the apparatus is only 30 pounds. Its general appearance is shown in plate 1.

The apparatus has satisfactorily passed severe tests. In use it is expected to prove more satisfactory than any such device hitherto available. Consequently, the United States will be independent of foreign makers of breathing apparatus for its future supply.

DEVELOPMENT OF PERMISSIBLE COAL-MINE EXPLOSIVES.

CHARACTER AND INCREASED USE OF PERMISSIBLE EXPLOSIVES.

The risks arising in the handling, transportation, and use of explosives have been lessened by the introduction of improved explosives for coal mines. In the past black powder was generally used in mines that were gaseous or contained dry coal dust, and many great mine disasters resulted. The Bureau of Mines seeks to have safer explosives used in dangerous mines, and to this end is testing explosives to determine their permissibility for such use. Those passing the tests are termed permissible explosives, and their use is urged in all mines containing gas and large quantities of bituminous coal dust. In the year 1908 only 2,000,000 pounds of these permissible explosives was used in such mines, whereas in 1915 the amount of permissible explosives had grown to nearly 22,000,000 pounds.

On October 1, 1916, 148 explosives had passed the required tests and had been placed on the Bureau of Mines list of permissible explosives.

MISCELLANEOUS TESTS OF PERMISSIBLE EXPLOSIVES.

Other tests to which permissible explosives are subjected are as follows:

Samples of the explosives on the permissible list are frequently collected for a chemical examination to determine whether they are similar in all respects to the samples originally tested by the bureau.

The products of combustion of explosives submitted for permissibility are examined for poisonous gases, and no explosive is admitted to the permissible list which gives more than 158 liters (5.5 cubic feet) of poisonous gases from 1½ pounds of explosive.

All explosives are examined for liability of the ingredients to exude from the containers.

The relative strength of detonators is determined by the sand test as perfected by the bureau.

TESTS OF DETONATORS AND ELECTRIC DETONATORS.

The Bureau of Mines not only tests explosives to determine their permissibility, but also prescribes the conditions under which they are to be used. One of these conditions is that permissible explosives shall be fired by a detonator, preferably an electric detonator, having a charge equivalent to that of the standard detonator used at the bureau's Pittsburgh experiment station. The grade of electric detonator is recommended by the manufacturer for use with a particular brand of permissible explosive; and should the explosive pass the required tests with the grade recommended, the same grade is prescribed by the bureau, but in no case can it be of less efficiency than a No. 6 electric detonator. A further requirement is that the charge of the detonator or electric detonator shall consist by weight of 90 parts of mercury fulminate and 10 parts of potassium chlorate or their equivalents.

The importance of these prescribed conditions may be realized by considering the means whereby permissible explosives are fired in practice. Detonators or electric detonators are required for firing all permissible explosives now on the bureau's list. Although the explosives might, in many cases, be partly exploded by the aid of squibs or fuse or by means of black-powder primers, yet the explosion so produced would not be complete; the explosives would not be used to their best advantage, and the gases produced would usually be dangerous. Therefore it is safer to fire detonating explosives with detonators or electric detonators strong enough to cause complete detonation.

The results of experiments made by the bureau show that the average percentage of explosives failing to detonate was increased more than 20 per cent when the lower grades of electric detonators were used instead of No. 6 electric detonators and was increased more than 50 per cent when these lower grades were used instead of No. 8 electric detonators.

DEVELOPMENT OF SAFER MINE ELECTRICAL EQUIPMENT.

For several years past the bureau has been working to bring about the retirement from mines of dangerous open-flame lamps and the substitution of the relatively safe electric lamp operated by a battery carried on the miner's belt.

The individual electric lamp, if generally adopted, will be a long step toward safety, as it cannot start fires or explosions as open-flame lamps may. Moreover, electric lamps give more light and distribute

1. FRONT VIEW.

2. BACK VIEW, WITH ALUMINUM PROTECTIVE COVERING REMOVED.

GIBBS OXYGEN MINE RESCUE APPARATUS.

1. TROUGH BARRIER IN PLACE IN A MINE ENTRY.

2. CONCENTRATED BARRIER AFTER A LIGHT, SLOW-MOVING EXPLOSION.

the light better than flame safety lamps, and thus the miner obtains the added safety attendant upon good illumination.

The bureau's method of procedure is to examine and test lamps submitted to it and to issue approval labels to such lamps as meet the requirements prescribed by the bureau as a minimum standard. Seven types of electric lamps have thus been approved.

When the work was first undertaken there were few portable electric lamps in use in mines and these were not entirely satisfactory. At the present time there are between 75,000 and 100,000 portable electric lamps in use in the mines of this country, and the lamps approved by the bureau are being adopted at an average rate of about 2,000 per week.

Several years ago the bureau approved the first explosion-proof electric motor. These motors are designed to prevent any explosion or flash within the motor casing from igniting gas in the mine air surrounding the motor. The type of motor brought out by the bureau's approval was not only permissible for use in gaseous mines, but represented a standard of construction considerably superior to anything previously in use. One other motor has recently received the bureau's approval. These motors have met with considerable favor and at the present time are being adopted at the rate of about 1,000 a year. The bureau has applications for the test of 16 other machines, the development of which is being carried on by the manufacturers as rapidly as the present congested condition of their factories will permit.

For the past two years engineers of the bureau have been developing a set of suggested safety rules for the installation and use of electrical equipment in bituminous coal mines. These rules which are now in course of publication, were developed in cooperation with outside mining engineers and mine operators, and are the result of many conferences and revisions. No practical requirement has been omitted that will make safer the installation and use of electricity in mines, and it is therefore believed that the adoption of the rules will greatly further the cause of safety.

The approval system of the bureau is to be extended to the mechanical equipment of mines when the laboratory facilities now being provided are completed.

GASOLINE LOCOMOTIVES FOR MINES.

To determine the conditions under which gasoline locomotives might be used in mines without detriment to the health of miners an investigation was made of the maximum amount of carbon monoxide which may be produced by gasoline engines. This maximum amount determines the desirable size and the manner of use of such locomotives in a mine and the amount of ventilation necessary.

PREVENTION OF MINE EXPLOSIONS.

For the past six years experimental explosion tests have been conducted at the experimental mine of the Bureau of Mines near Bruceton, Pa., in connection with the investigation of coal-mine explosions and their prevention. As a result of these tests two recommendations are now being strongly made by the Bureau of Mines in connection with the prevention of mine explosions—first, that under conditions prevailing in the majority of the mines of the United States rock dust be used for rendering mine road dust noninflammable and, second, that rock-dust barriers be used at various points in the mine for limiting any explosions that may occur.

USE OF ROCK DUST TO PREVENT COAL-MINE EXPLOSIONS.

Another method of rendering coal dust inert is by watering, but unless the water is frequently applied it often happens that for considerable periods the road dust of mines using this method is not in satisfactory condition, because the water rapidly evaporates and leaves the dust dry; consequently the rock-dust method is strongly advocated, inasmuch as rock dust will give protection for much longer periods of time than will the application of water.

In the use of the rock-dust method the coal dust is removed from the mine roads as completely as possible and all the surfaces throughout the mine are then coated with dry pulverized rock dust. As the road dust will be gradually coated with an accumulation of coal dust it is desirable when the percentage of combustible dust reaches a certain figure that more rock dust be distributed. This is usually done by a so-called "rock-dusting machine."

In the event of an explosion the pressure wave that travels ahead of the explosion raises the road dust in a cloud and if this cloud is largely composed of incombustible material it tends to blanket the flame of the explosion and limit its travel. The rock-dust method has been tried in one mine in Colorado for a period of about five years and in three mines in Pennsylvania for periods of one to two years. It is believed that the method will be extensively used in the future.

ROCK-DUST BARRIERS.

A rock-dust barrier consists of a number of boxes or shelves filled with rock dust, which in the event of an explosion is automatically dumped, resulting in the formation of a thick cloud of rock dust and the blanketing of the flame. The plan of using the barriers is to place them at the entrances of panels or sections of the mine, so that if an explosion occurs in a panel or section so protected, it can not travel beyond, or if the explosion occurs in another part of the

TROUGH BARRIER.

1. CLOUD OF DUST CAUSED BY THE DISCHARGE OF ONE OF THE TROUGHS OF A TROUGH BARRIER IN A MINE ENTRY.

2. SAME CLOUD FROM A DIFFERENT POINT OF VIEW.

mine it can not travel into a protected panel or section. The use of the barriers should be supplementary to rock dusting or to the watering method of rendering the coal dust inert. If the watering or rock-dusting method fails and an explosion is propagated beyond its origin, then the barriers should be effective in limiting the explosion to the particular section of the mine in which it originates.

The original barrier, invented by J. Taffanel, of France, consisted of 10 to 15 shelves placed across the entry just beneath the roof, spaced about 10 feet apart, and loaded with rock dust. This barrier had two disadvantages: (1) If the explosion was light and slow moving it might pass under the barrier without discharging enough dust to quench the flame; and (2) the dust was exposed to the mine atmosphere, and under some conditions would become wet and packed, so that it was no longer in condition to be efficient in case of an explosion. Accordingly, a number of different types of rock-dust barriers were invented by George S. Rice, chief mining engineer of the Bureau of Mines, which did not have these disadvantages. All of these barriers are operated by the explosion itself through a leverage system sensitive to low pressures; the dust compartments are totally inclosed so that the dust is not exposed to the air current.

The bureau has tested and found satisfactory four different types of rock-dust barriers, namely, the trough barrier, the concentrated barrier, the door barrier, and the rock-dust stopping. The trough barrier and the concentrated barrier can be placed at any point in a mine entry high enough to permit their erection. Each type has a swinging board vane 100 feet beyond the barrier in each direction, these vanes being connected by a wire to the operating mechanism. When the explosion swings the vane it causes the barrier to dump the dust into the air current. Each type retains a certain amount of dust near the roof so that in case there is an interval of some seconds between the operation of the barrier and the passage of the flame, there will still be dust in the barrier to be dislodged by the pressure accompanying the flame and to quench the flame.

Plate 2, figure 1, shows a trough barrier in place in a mine entry. The wires connecting the barrier troughs with the vane can be seen on either side of the entry near the roof. When the barrier operates, the bottom boards drop as shown in plate 3, and a thick shower of dust falls into the entry.

Plate 4, figure 1, shows a cloud of dust caused by the discharge of the dust from one of the troughs.

Plate 4, figure 2, shows the same cloud from a different point of view.

Plate 2, figure 2, shows a concentrated barrier after a light, slow-moving explosion. Before an explosion the shelves of this

barrier are all held in position near the roof. When the explosion operates the barrier, however, the shelves fall to the positions shown, and much of the dust is discharged into the entry.

The door barrier consists of rock-dust compartments on both sides and above a mine door, the barrier being held in place by the frame of the door. If an explosion blows the frame out of position the entire barrier collapses and a large amount of dust is discharged into the air.

The rock-dust stopping consists of two vertical rows of shelves, one on each side of a stopping or wall, loaded with rock dust. In the event of an explosion the overturning of these sets of shelves, or the force of the explosion through the shelves causes the formation of a dense dust cloud that cools the flame.

ROCK-DUST BLOWER.

Plate 5, figure 1, shows a rather crude type of rock-dust blower, with a chamber into which the dust can be fed from a hopper.

Plate 5, figure 2, shows the dust being discharged through a hose. This blower is used to blow a thick cloud of dust into the air current, by which it is carried for considerable distances, when it settles down as a mantle over whatever coal dust there may be in the mine road or entry, and renders the coal dust much less likely to assist the propagation of an explosion. The machine is particularly useful in carrying the dust into entries that are accessible only with difficulty.

IMPROVED MINE-GAS DETECTOR.

Although the electric safety lamp, as compared with flame safety lamps, is much safer in gaseous mines, not alone because it will not under any conditions ignite the gas present, but because it gives a better illumination than the flame safety lamps, it does not take the place of the flame safety lamp in one of the latter's most important functions, namely, that of testing for the presence of dangerous gases.

There has long been a demand for some sort of an indicator or detector with which the presence of inflammable gas could be determined more accurately than with a safety lamp. Such an indicator, called the Burrell gas detector, has been developed by one of the chemists of the bureau. For determining the presence of inflammable gases it has an advantage over a flame safety lamp because its use eliminates any error due to defects of vision, and anyone can easily determine the exact amount of gas present. Thus the detector not only makes unnecessary the use of the flame safety lamp but enables the proportion of gas present to be determined to within 0.1 per cent. The flame safety lamp enables the miner to estimate only roughly the amount of gas present.

1. ROCK-DUST BLOWER.

2. DUST BEING DISCHARGED THROUGH A HOSE.

BURRELL GAS DETECTOR.

Moreover, the use of the detector is not limited to mines or to detecting fire damp, but it can be used for proving the presence of any combustible gas, such as gasoline vapor, hydrogen, natural gas, or coal gas.

Essentially, the detector consists of a U-tube, one branch of which is inclosed in a metal case, as shown in the accompanying photograph (pl. 6). To make the device ready for use the top *a* is unscrewed and water is poured in until it fills the two branches and rises to the zero point *b* on the scale.

To make a determination of combustible gas, say methane, in mine air, the valve *c* is opened, and by blowing gently into the reservoir the operator depresses the water column along the scale and forces it up to the top on the other side. A slight click when the water strikes the valve *c* tells the operator that it has risen to the required height. Then the operator pinches the rubber tube *d* and takes the instrument to the place where the sample is to be collected. When the pressure on the rubber tube *d* is released, the water immediately comes back to its original position, and on falling sucks through the valve *c* a sample of the air to be tested.

This sample rests in the combustion chamber *e* in contact with a platinum spiral. The valve is closed and the spiral is electrically heated by use of the binding posts *f*. Any combustible gas in the sample immediately begins to burn and at the end of a minute and a half is completely consumed. The electric current is then turned off and the instrument is shaken, thus forcing the water into the combustion space *e* and cooling the gases. Immediately the water column on the open-tube side falls to some point on the graduated scale as *x*, the exact point depending on the percentage of methane present. The scale reading opposite the water level shows the percentage.

The platinum wire can be heated by means of the storage battery of a miner's electric cap lamp, the battery being carried on a man's belt, and the current being switched from the lamp to the detector, as the tests are made.

The device is 10 to 20 times as accurate as the safety lamp, weighs less, and has fewer and more durable parts.

PORTABLE APPARATUS FOR RAPID DETERMINATION OF INCOMBUSTIBLE MATTER IN ROAD AND RIB DUSTS FROM COAL MINES.

In applying rock dust in mines it is necessary to determine quickly and on the spot the approximate percentage of noncombustible matter in the road and rib dust in order to determine how much additional limestone or shale dust is required to prevent the propagation of dust explosions.

For this purpose the Taffanel volumeter has been modified and combined with a convenient portable field equipment. The complete

outfit is shown in plate 7. It weighs approximately 20 pounds. The carrying case is made of $\frac{3}{8}$-inch poplar, dovetailed at the corners and brass bound, and is provided with a cover and a handle. The outside dimensions are 7 by 13 by 14 inches high, which is large enough to furnish ample room for all the required apparatus, cans of alcohol, extra supply containers, etc. The outfit consists of the volumeter *a*, the pipette *b*, the balance *c*, the funnel *d*, the alcohol can *e*, the sampling scoop *f*, the sampling cloth *g*, etc.

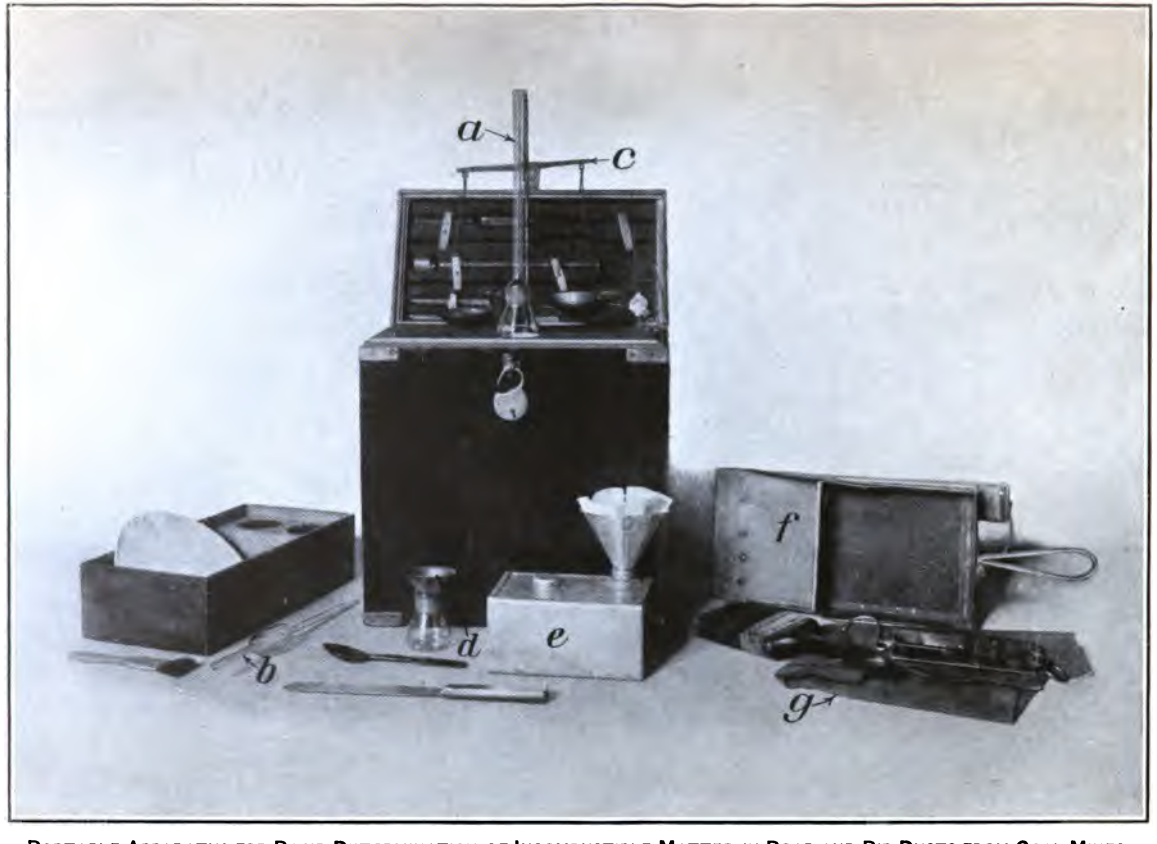
A determination of the percentage of combustible matter in a given sample of dust is made as follows:

Twenty-five cubic centimeters of alcohol is measured into the volumeter flask with the pipette; 20 grams of the dust to be tested is then poured in. The graduated tube is inserted in the flask, and the dust and alcohol are thoroughly mixed by shaking, after which 25 cc. more of alcohol is added from the pipette through the stem of the volumeter, all adhering particles of dust being carefully washed down.

After one minute the scale reading of the meniscus is taken, and by reference to tables the percentage of noncombustible is obtained.

The placing of this apparatus at the disposal of the employees of the bureau will enable them to determine whether the dust hazard in any mine in their district is such as to warrant treatment to prevent a dust explosion.

It is further expected that when this apparatus becomes available for general use it may result in calling the attention of mine operators to dangerous dust conditions that might otherwise eventually cause disastrous explosions.



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